DEBRIS OPERATIONAL SUPPORT THROUGH WEB APPLICATIONS

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ABSTRACT

ESA's Space Debris Office made the strategic decision to use web applications for providing key services to external and internal users, all with a common modern look and feel with the end user experience in mind. The services supported with web applications are collision avoidance support for mission operations and atmospheric re-entry prediction. Three applications are presented, two of which are already being used, and a third one still under development. The first two support the tracking of close approach events and visualization of conjunction geometries respectively. The re-entry tool, which is still under development, will allow interaction between analysts based in ESOC and end users, many of whom are national alert centers which expect to be informed of any foreseen risks to national populations.

Index Terms— operational support, collision avoidance, atmospheric re-entry, web application

1. INTRODUCTION

With the growing number of debris and satellites which ESA operates, the necessity for operators to mitigate collisions with debris is a reality. Meanwhile atmospheric re-entry of objects is also gaining lots of media interest.

In order to enhance ESA's Space Debris Office's (SDO) operational support to missions and to national alert centers, CGI has been developing web based tools which improve decision making speeds, decision quality and end user experience in general. The tools also allow scaling up operational support to more missions, being it ESA's or external ones.

What are being developed are essentially front-ends for displaying data from the SDO's databases or generated from SDO's computations. The display of data are in tables, graphic plots or 3D visualisations and is split in views which are specifically adapted to the role of the user, e.g. satellite operator, debris analyst or manager. Among the multiple functionalities, an important one is the possibility to display multiple collision avoidance manoeuver scenarios so that trajectories and close approach geometries can be compared.

The applications were developed with powerful web technologies, have a common visually appealing look-and-feel and have been developed with continuous user feedback, such that the ergonomics are adapted to the SDO's work flow as well as to the needs of the SDO's customers within ESA and outside.

2. RATIONALE FOR WEB APPLICATIONS

The SDO's new tools being web based, they are extremely straightforward to deploy and install because they only run in one place and therefore there is no other requirement on the client side than to have a modern browser and a decent graphics card for running the 3D visualisation tool smoothly. Web applications allow access to the SDO's services very easily for third parties, e.g. external customers. Moreover, the maintainability of the tool is easy through the maximum reuse of modern and industry-established web technologies which help avoid reinventing the wheel. There are a plethora of technologies available, which are supported by a thriving community. Making use of these technologies helps the development team to focus on what really matters, i.e. put the right bricks together in the right way.

The front end communicates with the backend with a REST API there is a layering in the back end in such a way that data to be displayed can be retrieved from various types of databases. In the case of ESA's Space Debris Office, data are retrieved from a PostgreSQL database.

All tools benefit from a common look and feel and of a common central authentication.

The development was done in an Agile methodology using the Scrum framework. This entailed frequent deliveries of the latest releases which could then be tested by the customer who could provide feedback continuously. Not having an initial set of rigid low level requirements upfront allowed to have all the flexibility necessary to develop a new tool which was ultimately adapted to the end users' needs.

3. MANAGING CLOSE APPROACHES

The management of close approaches is performed by PREEMPT Manager. Its purpose is to make the tracking,
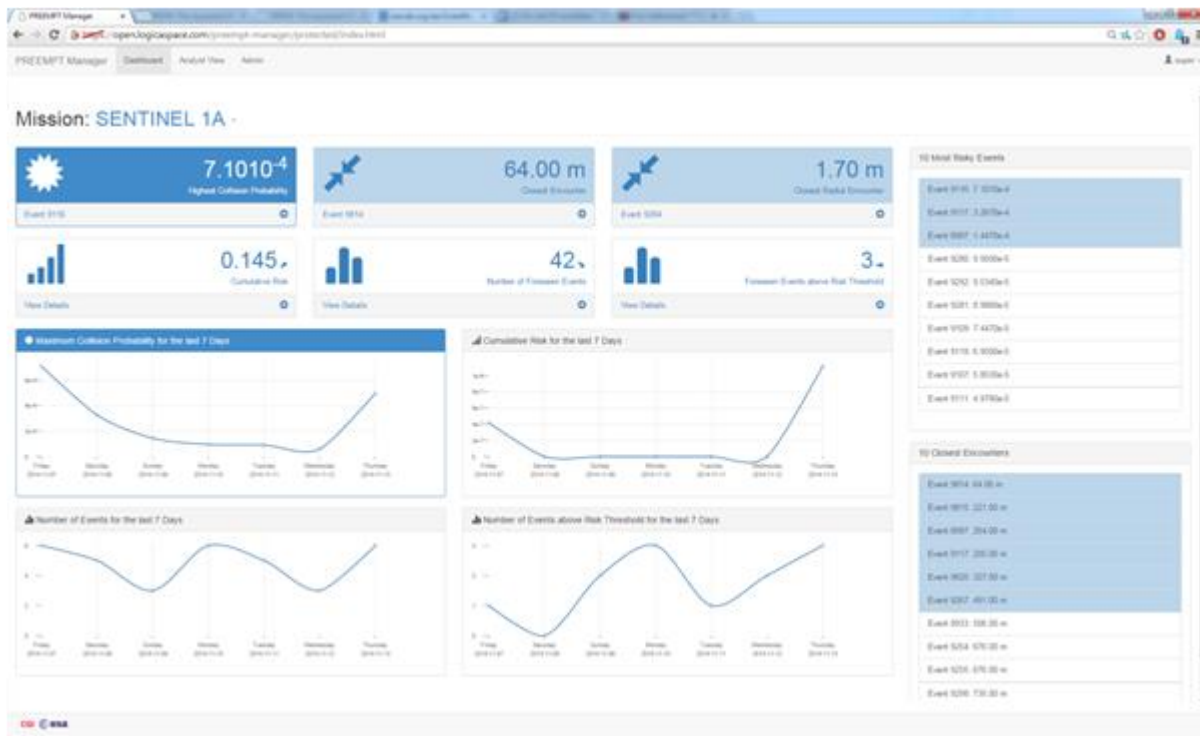
Figure 1. Dashboard view of PREEMPT Manager

analysis, management and information sharing of conjunction events easier and more unified. These conjunction events consist of a set of CDMs and are in one of the following statuses: unassigned, assigned, escalated, manoeuver, closed, or archived. Indeed, each CDM can be given an assignee and can be marked as checked by that person.

This person can then escalate a potentially threatening event by sending an email to the Flight Control Team from within the tool with one click of a button, in order to raise awareness of an event that is worth paying attention to.

A dashboard view serves as a landing page summarizing the state of events for each mission. These are for example tables of most events with the highest risk of collision or plots of trends of the maximum collision probability in the last seven days. This view provides a high level overview of the threats that the mission is facing in comparison to past trends.

An analyst view gives access to the data on all events, CDMs, physical properties of target and chaser across all the supported missions. This is clearly a large amount of data, therefore sorting and filtering can be done on all data. Users can comment the events and share their comments with other members of their own team or of other teams.

The tool has a feature that allows generating reports in a template that can be customised. It is also possible to send emails from within the tool with customisable templates.

The log feature displays textually and graphically all actions related to each event, from its creation to assignment of owners, to creation of new CDMs, update of CDMs, escalation, closure.

In the back-end, the software interfaces with a database containing all CDMs and other information. Accounts can be easily set up for operators wishing to follow events more closely.

The PREEMPT visualisation tool can be opened for any event and CDM, allowing to compare CDMs and the effect of manoeuvers on the conjunction geometry.

4. VISUALISING CLOSE APPROACHES

In order to analyse the geometry of close approaches, PREEMPT is used a web-based high-fidelity 3D visualisation tool. Its objective is to provide the satellite operators with a high fidelity visualisation of conjunction geometries, to make it easier for them to understand the situation immediately. It is used for the decision making process about whether to implement an avoidance manoeuvre or not. Flight Control Teams find it often very
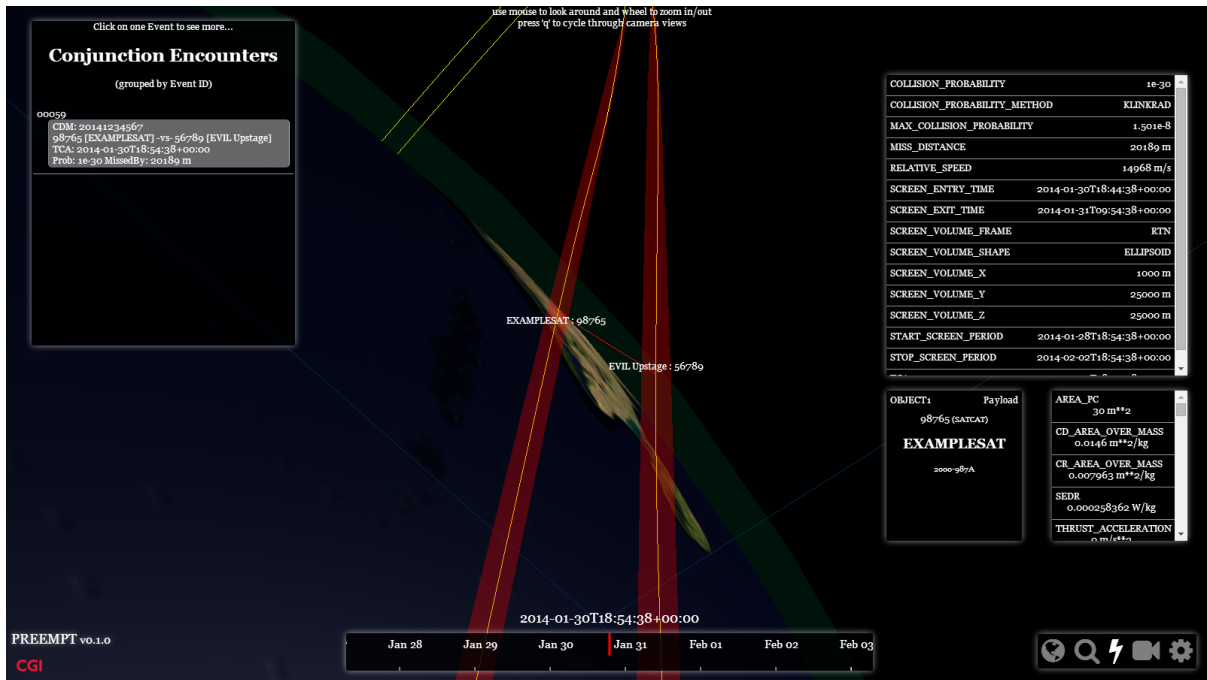
Figure 2. View of the close approach and corresponding covariance in PREEMPT

convenient to visualise close encounters on a screen, instead of mentally trying to visualise and interpret the numerical data within Conjunction Data Messages (CDMs). Such a tool is a support for improving the communication between satellite operators and debris specialists, ultimately paving the way for faster and more confident decisions on whether to execute a corrective manoeuver or not.

PREEMPT runs in a web browser with no plug-ins. It has multiple features. The user interface is highly responsive and has a modern look and feel. Various camera views are supported: on-board the target or the chaser, centered on the event, centered on the Earth or following the target or the chaser. Multiple Conjunction Data Messages (CDMs) related to the same event can be compared simultaneously and one can see the effect of an avoidance manoeuvre on the conjunction geometry.

The covariance ellipsoids are displayed and their size in terms of variance can be adjusted.

A time scrubber allows playing with the time back and forth with adjustable speed to visualise how the two objects and their covariance ellipsoids approach each other. This can be done from any camera view.

Textual information about the conjunction event and the physical properties of the target and the chaser can be displayed upon request in an uncluttered manner.
The driving concept behind the user interface design was the reuse of concepts in the gaming industry where the right

information should be displayed in the right way in the right place in the right time.

5. MANAGING RE-ENTRY EVENTS

A third web application is still in development and will be used for tracking atmospheric re-entry events and share information with users. The most important users of the tool are national alert centers.

A Public view shows a static view with images, plots, banners, news items updated by the host. This allows a high level overview of the situation without focusing on any specific mission.

Registered users are allowed to access more detailed and accurate data related to specific missions and re-entry events. Registered users can also exchange messages directly with ESOC's re-entry analysts.

Multiple views support the easy understanding of the re-entry events. The Gantt chart view shows the objects expected to reenter or which have reentered. The chart has a dynamic graphical view which also displays the uncertainty corresponding to the time of re-entry. The graphical view has a brush in bottom which allows easy zooming in and out and pan to specific dates the user wants to see.

The Table view shows the latest prediction of all re-entry objects in the time window in tabular form. This view
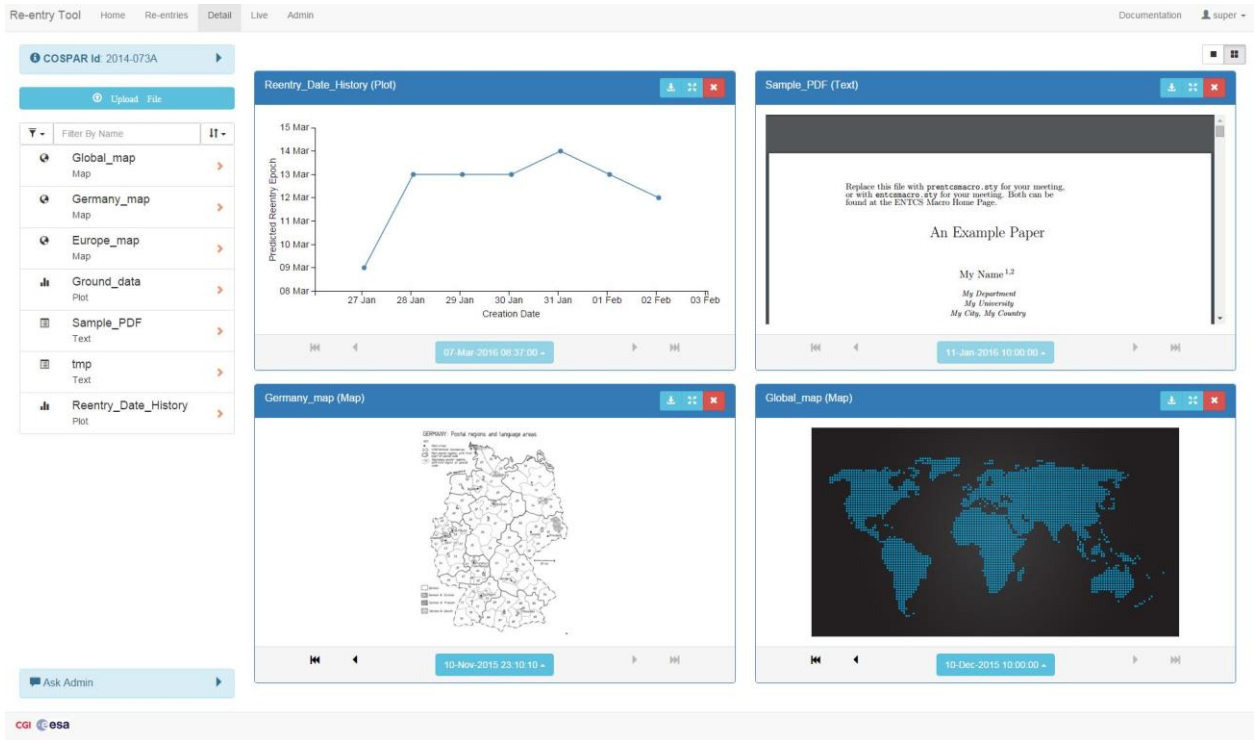
Figure 3. Preliminary illustration of the Detail view in the re-entry application

displays all the available numerical information related to the re-entry.

Because the number of events can become large, both the Gantt chart and the table view have a common intuitive filtering and sorting functionality which allows the user to select and order the data they want to specifically see.

A functionality called Ask Admin allows a user to ask generic questions to the ESOC analyst and get replies back. This communication is only available between user and analyst; user to user is not supported. The analysts, in their own dedicated view, get the list of all users who have sent a new message and upon clicking a user sees their message.

A Detail view shows additional information of a particular event in the form of displayed files. These files are generally the outputs of analyses. These files can be plots, maps, images or textual documents.

To compare multiple files the user can select multiple views and compare files displayed next to each other.

Dynamic plot showing re-entry date evolution is plotted and rendered as one of the files.

List of files can be filtered and sorted from the filter panel and all the files can be downloaded.

The user can also request restricted access to an event which allows them to have access to further details on the object.

If the user wants more information on the event beyond those available through restricted access, it can contact the analyst via the Ask Admin panel. This panel is present in the view for that specific event. Same as in the re-entry view, analysts get the list of all users who have sent a new message and upon clicking a user sees the message and has the possibility to respond.

An Admin view is dedicated to the re-entry analyst located in ESOC. It allows the analyst to give and revoke re-entry specific privileges to the end user. It also allows the analyst to reply to user messages.

Filters are available in this view for the analyst to select user emails and event IDs.

Many established and modern web technologies are applied on the client side to create a compelling look and feel and ease the development and maintenance of the tool. These technologies are mostly Javascript libraries.

The client communicates with the back end with a REST API. The databases running in the backend are based on MongoDB and PostgreSQL.

9. CONCLUSION

ESA's SDO made the decision to provide access to key services to its customers through web applications with a common look and feel and central authentication. The applications were developed for ESA by CGI for helping with the operational support of space missions by ES and atmospheric re-entry prediction for national alert centers among others. The conjunction applications are being used for multiple missions already. National alert centers will benefit from improved service through a re-entry prediction application soon.

Providing services through web applications has multiple advantages for all parties involved, i.e. the SDO, its customers and the application developers. End users always benefit from the latest updates while development and maintenance costs are reduced thanks to the ease of deployment and use of a thriving ecosystem of established and powerful web technologies.